DE LA RECHERCHE À L'INDUSTRIE

Stony Brook University 10th RD51 Collaboration Meeting

Ageing studies of resistive Micromegas prototype for the HL-LHC

D. Attié, J. Derré, E. Ferrer-Ribas, J.Galan, A. Giganon,
I. Giomataris, T. Giron de Faucher, F. Jeanneau,
R. de Oliveira, P. Schune, J. Wotschack

On behalf of MAMMA collaboration

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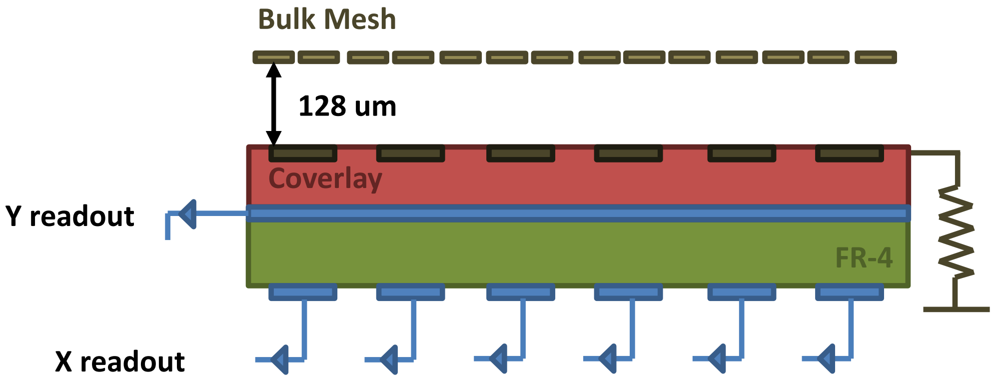
Outline

Two similar resistive prototypes available

One irradiated and the other is a reference

1. X-ray generator
2. Low energy neutron beam
3. Intense gamma source
4. Alpha irradiation

Resistive prototypes under test (2D readout)

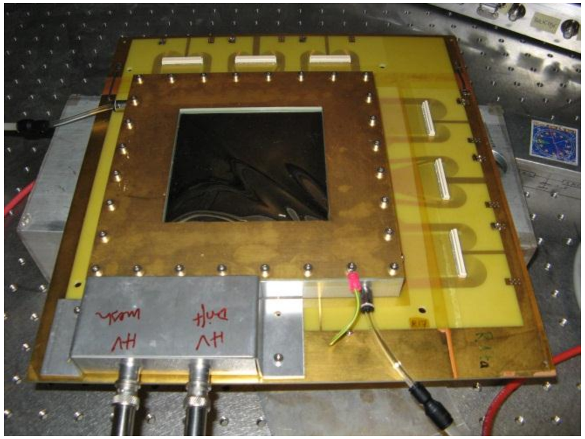


Two resistive prototypes (R17) were sent to Saclay for performing aging tests

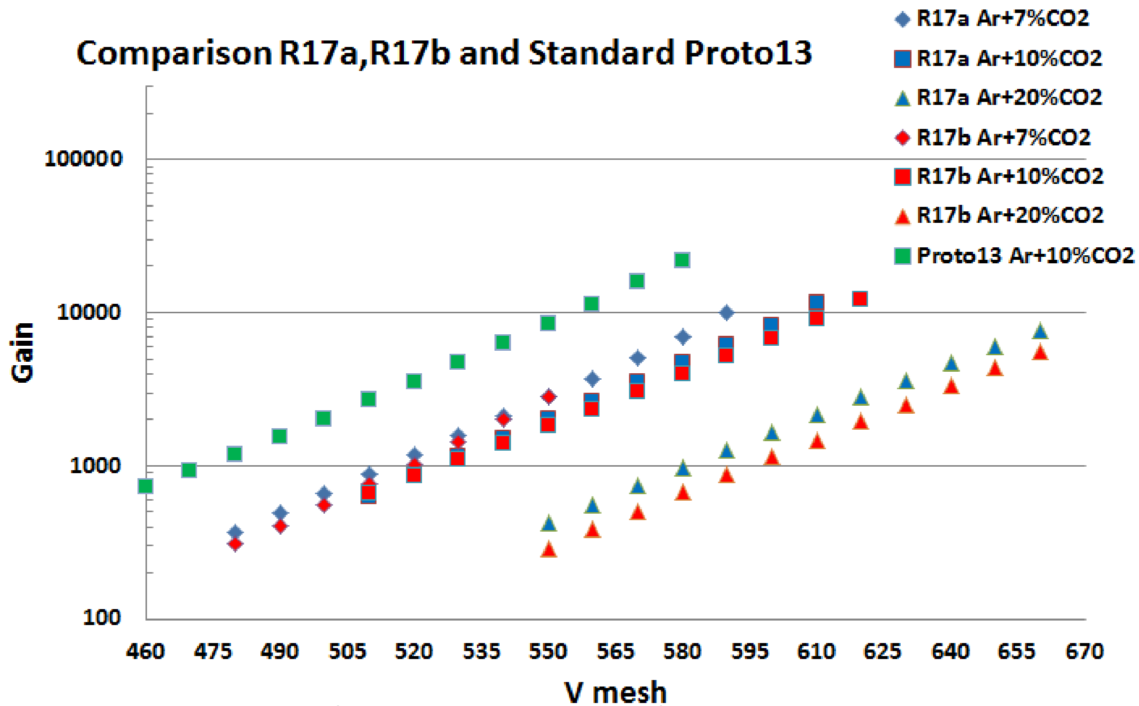
17A	Resistance to GND: 80-140 MOhm Resistance along strips: 45-50 MOhm/cm
17B	Resistance to GND: 60-100 MOhm Resistance along strips: 35-40 MOhm/cm

Geometrical properties

Strip pitch/width for all: **250 µm/150 µm**
Top layer (Resistive strips): **35 µm thick**
Insulation (coverlay): **60 µm**
Y strips (90 degrees to R strips): **9 µm Cu**
Insulation (FR-4): **75 µm**
X strips (same direction as R strips): **9 µm Cu**



Both detectors show similar gain properties
Re-characterized at CEA for different gas mixtures



X-ray generator irradiation

Equivalent charge generated during 5 years HL-LHC

Wi (Argon + 10% CO_2) = 26.7 eV
Gain = 5000
MIP deposit in 0.5 cm drift = 1248.5 eV

Charge per iteration = 37.4 fC

Expected rate at the HL-LHC : 10kHz/cm²

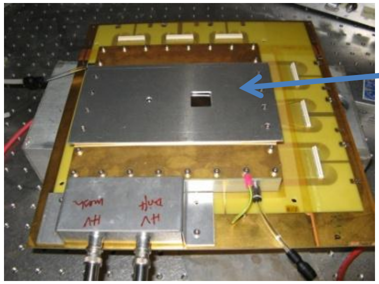
5 years of HL-LHC operation (200days X year)

Total detector charge generated during HL-LHC operation is estimated to be 32.5 mC/cm²

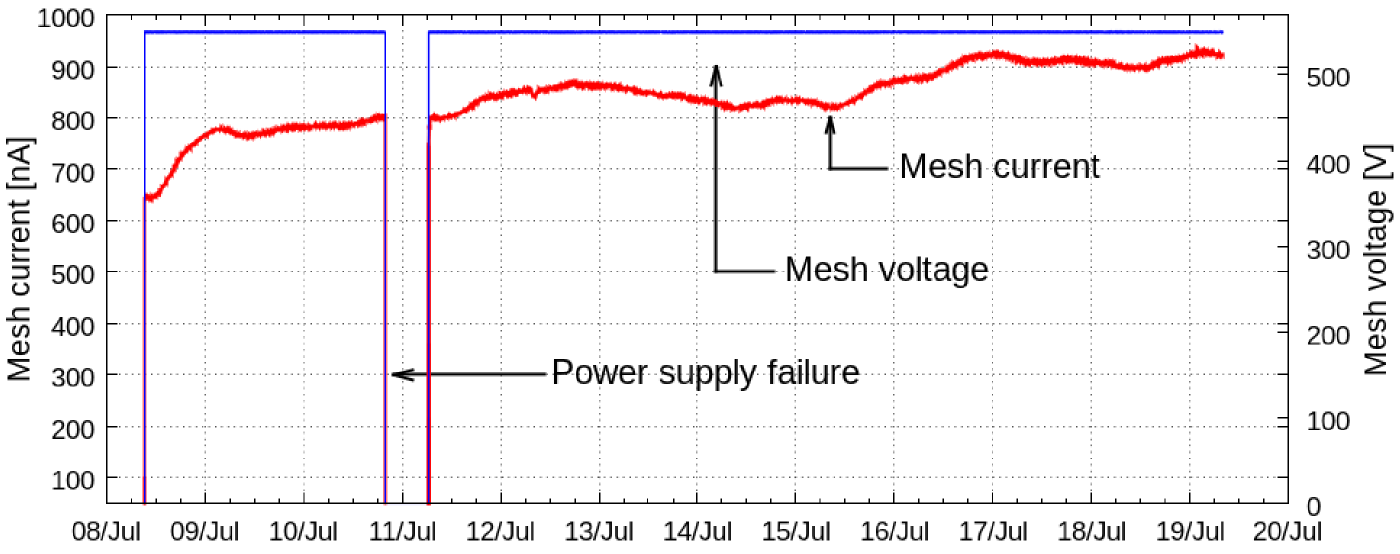
Detector operated in data taking conditions

Gas mixture : Argon + 10% CO2
Gas Flow = 0.5 l/h
Gain 3000
HVm = 540V
HVd =790 V

X-ray generator set-up at 10 kV 5 mA



X-ray exposure in a small active area region of 4 cm².



X-ray generator irradiation

During the X-ray ageing test it was generated a total charge of

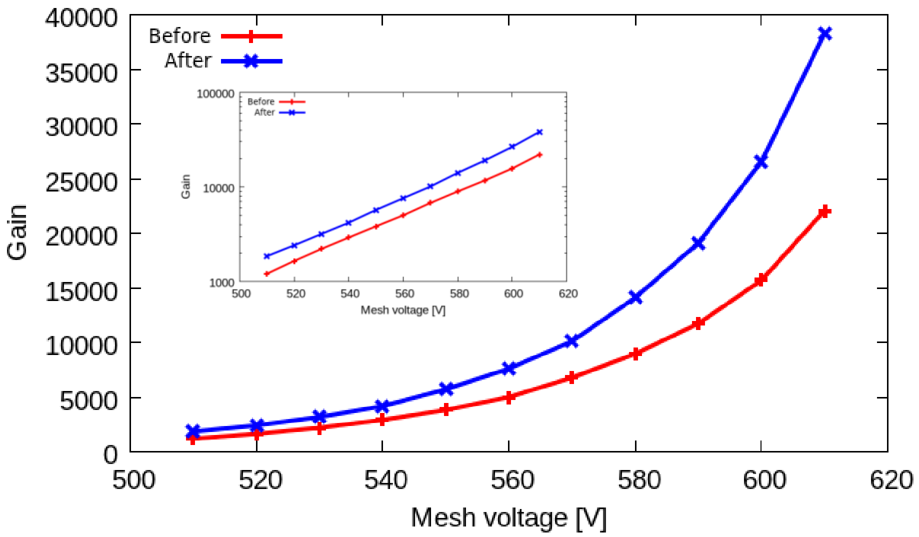
Q_{ageing} = 765mC in 4cm^2,

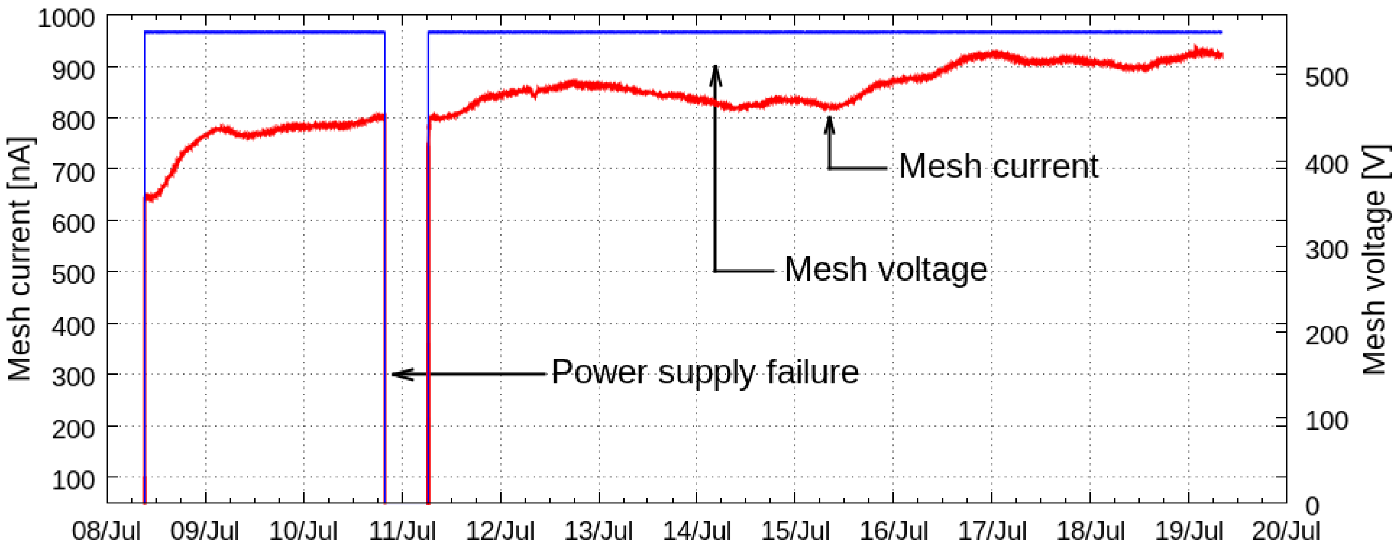
during a total exposure time of

$T_{exposure}$ = 11days 21 hours

And therefore, the total charge to be generated at the HL-LHC during 5 years with more than a factor 5 of security factor.

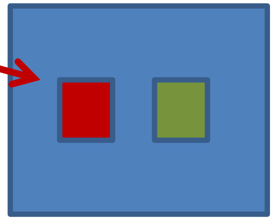
Detector gain was not degraded at the area of X-ray exposure





X-ray generator. Second X-ray exposure (October 2011)

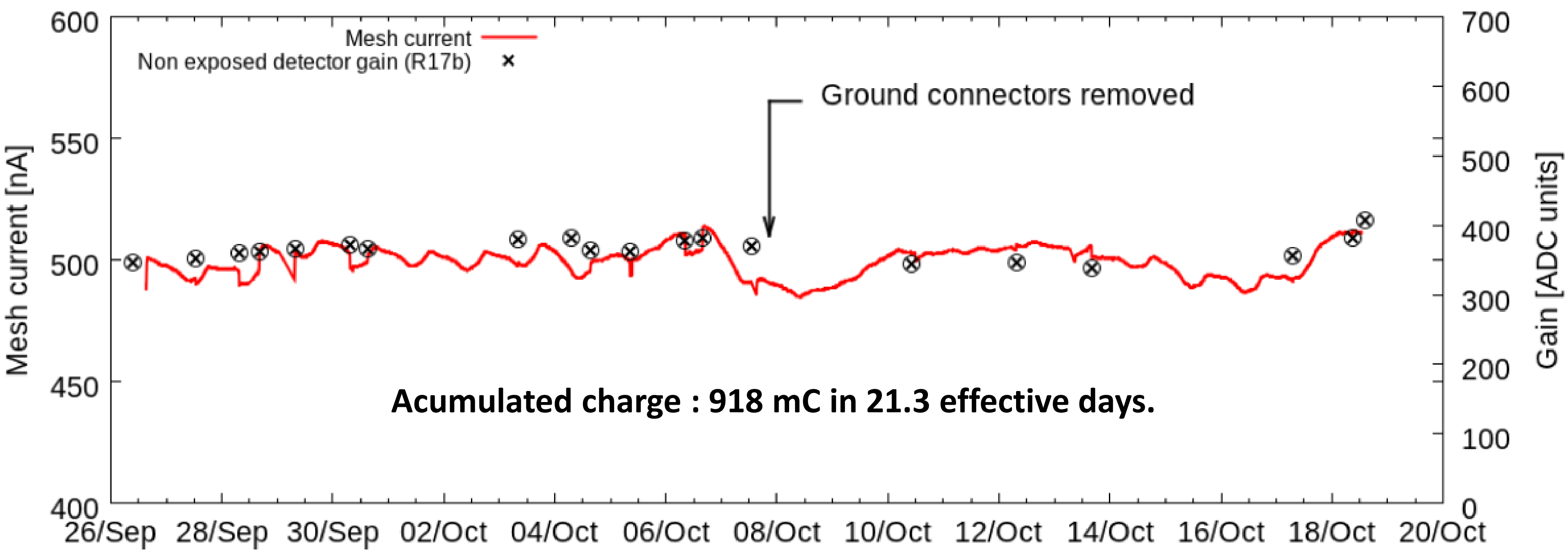
Second irradiation period had place at a different region of the detector

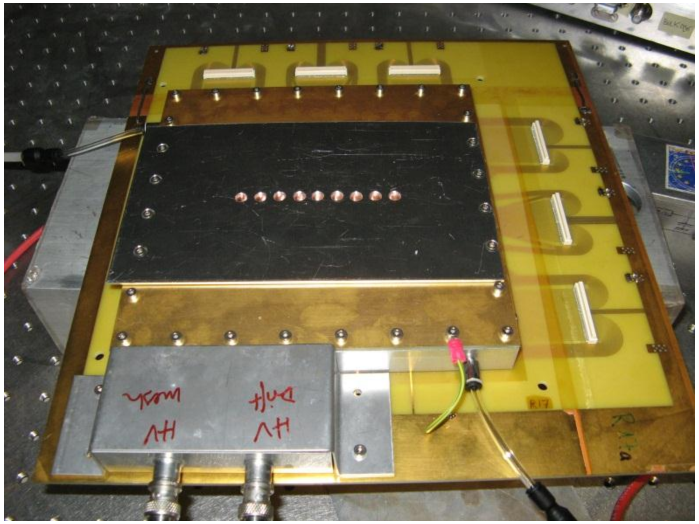


Tests were re-taken in order to verify the results obtained.

Moreover, during the second aging period <u>the second detector (R17b) is connected in parallel</u> (without being exposed), and it is <u>used to do gain control measurements</u> to cross-check the gain changes coming from possible enviromental effects on gas mixture.

Additionaly, in this second period, <u>control gain measurements in the exposed detector (R17a) were done at different positions</u>, before and after the irradiation.



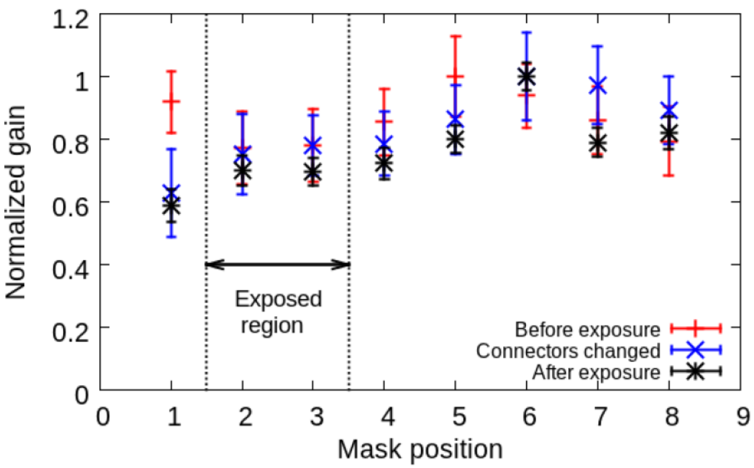


Measurements at different position were performed by using a mask with several equi-distant holes over the active region of the detector.

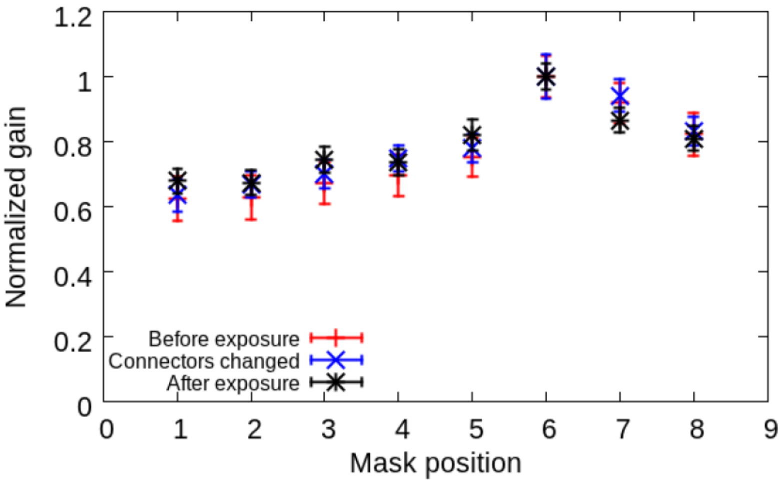
Normalized gain measurements show the relative compatibility with position.

The exposed region does not show a considerable change respect to the non-exposed regions.

Exposed detector R17a



NON Exposed detector R17b



Neutron aging tests at Orphee reactor.

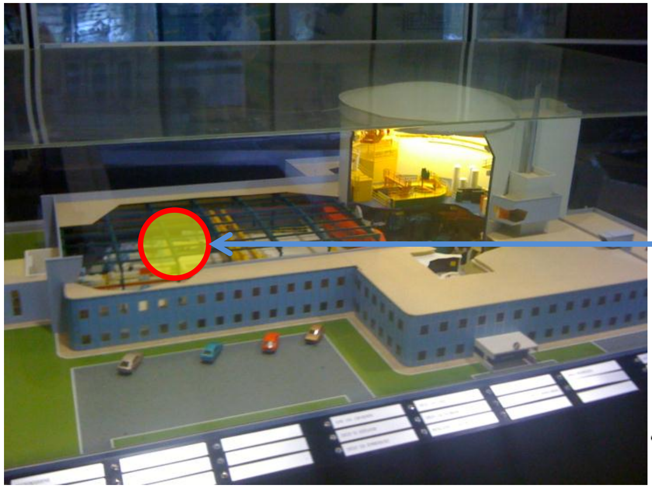
High intensity thermal neutron irradiation had place at C.E.A. Orphee reactor.

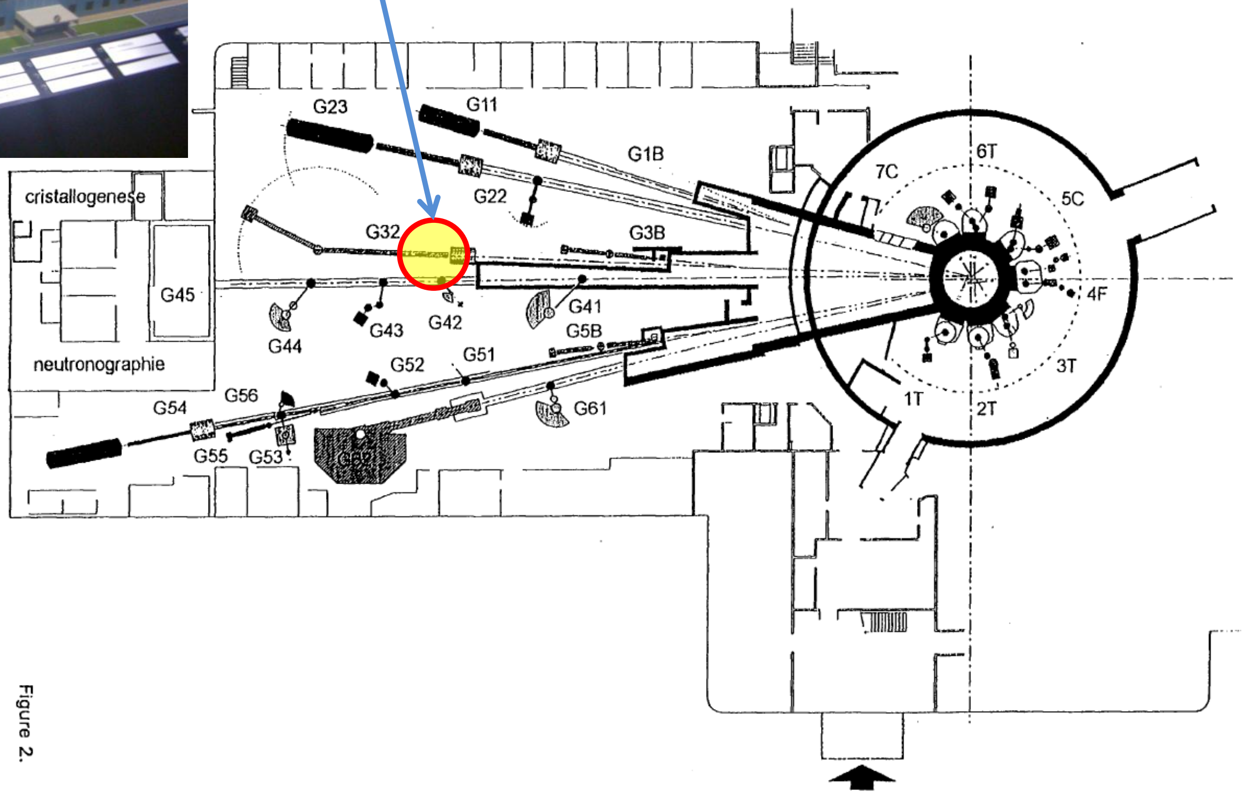
Several neutron research lines available.

Neutron flux : ~8.10^8 n/cm2/sec

Neutron energy : 5 to 10 meV

Detector emplacement at Orphee reactor Neutron guide



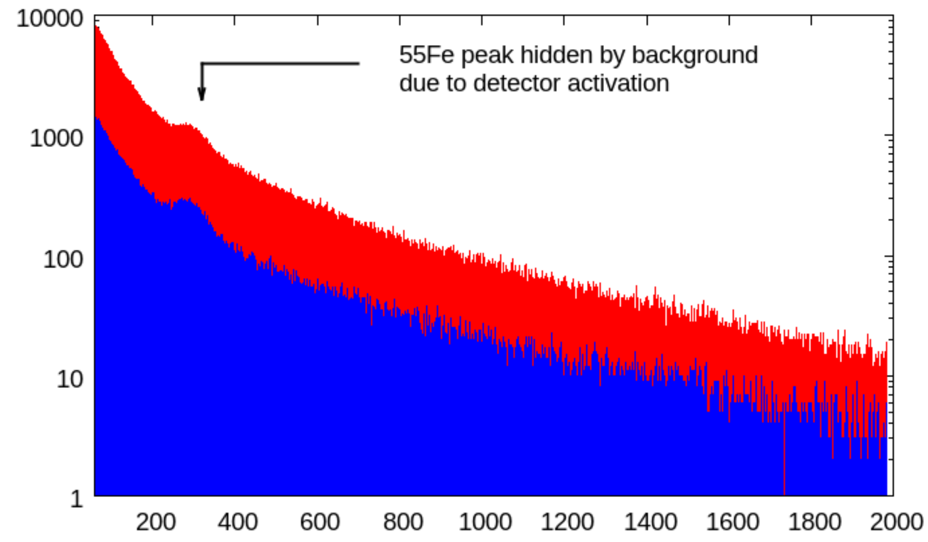


Detector activation after neutron exposure

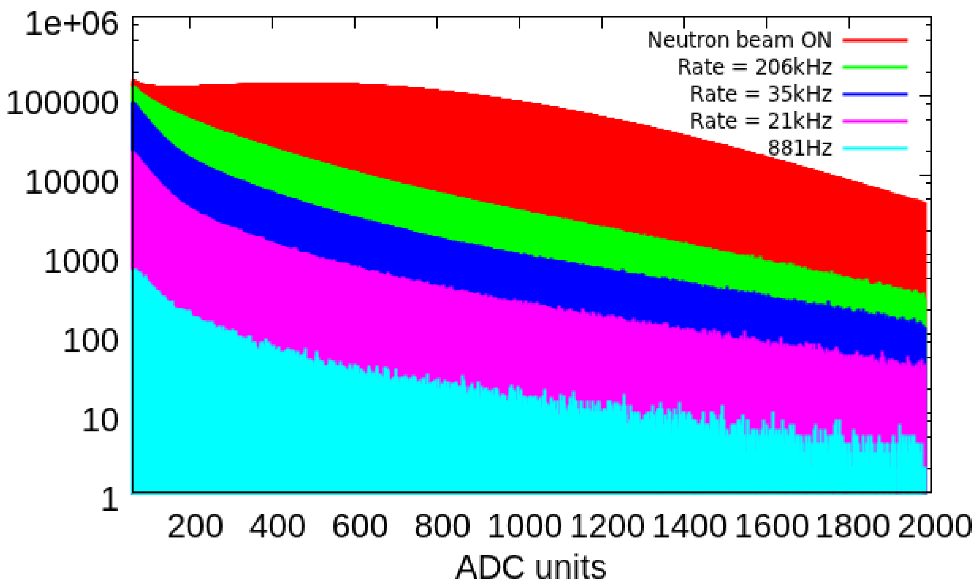
After a short irradiation period the detector is quickly activated and takes long time to deactivate.

The activation rate measured saturates and reaches a limit of about 250kHz which does not increase with exposures longer than 2 hours.

After 5 minutes neutron exposure



After a period of 2 hours exposure



Time	Rate
11h08	206 kHz
14h04	35 kHz
16h03	26 kHz
18h16	21 kHz
8h52*	881 Hz

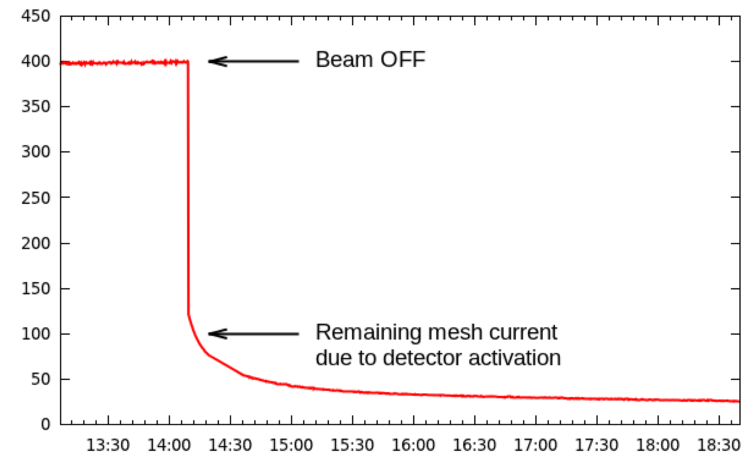
Detector ageing history during neutron tests.

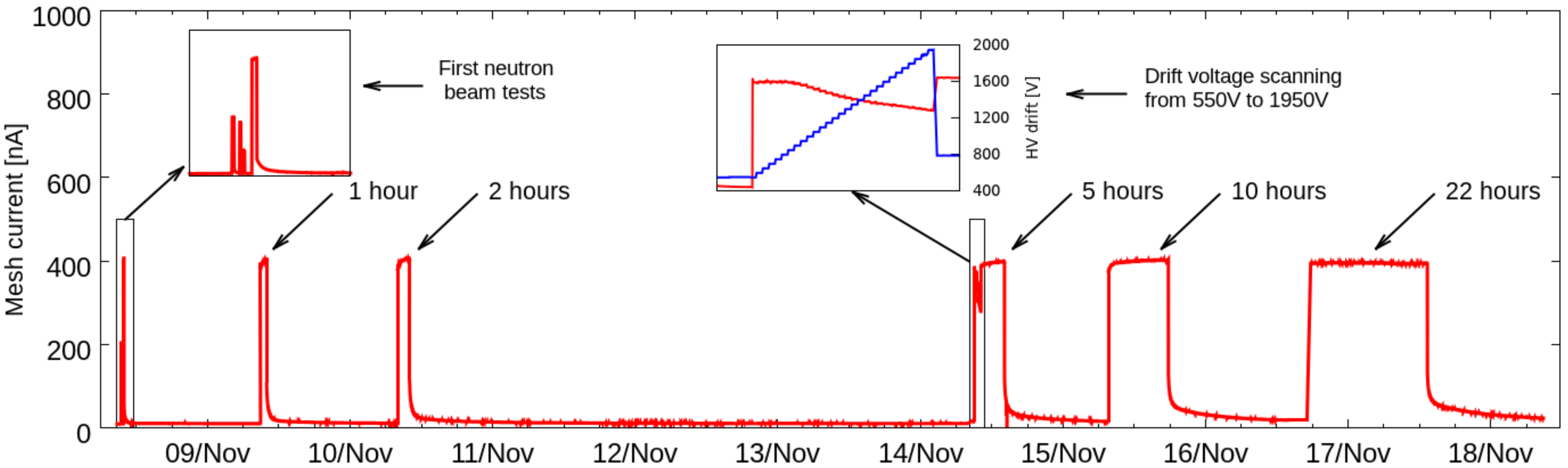
Neutron flux at the level of CSC in ATLAS ~3.10^4 neutrons/cm2/s

10 years at HL-LHC (=> x10.10^7 sec) with a security factor : x3

At the HL-LHC, we will accumulate 1,5.10^{13} n/cm2

At Orphee we have ~8.10^8 n/cm2/sec so in 1 hour we have : 8.10^8 x 3600 ~ 3.10^{12} n/cm2/hour which is about 2 HL-LHC years (200 days year).





HL-LHC expected gamma flux

LHC -nominal condition- prediction
(from Background task force, ATL-GEN-2005-001)

Position	Fluences (kHz/cm²)				Currents (Hz/cm²)			
	Neutrons			Photons	Ch.hads	Protons	μ^{+-}	e^{+-}
	Total	>100keV	>10MeV	>30keV	>10MeV	>10MeV	>10MeV	>0.5MeV
Barrel								
1st,low-z	5.08	1.47	0.10	1.81	2.79	1.89	1.89	9.30
1st,high-z	5.25	1.47	0.07	1.88	2.24	1.86	2.55	13.29
2nd,low-z	4.97	1.20	0.10	2.19	0.69	0.64	0.37	7.00
2nd,high-z	6.28	1.72	0.30	4.14	1.88	1.81	0.77	11.81
3rd,low-z	4.45	0.86	0.08	1.90	0.32	0.31	0.09	5.96
3rd,high-z	4.87	1.02	0.18	2.71	0.98	0.97	0.39	8.10
Forward								
1st,low-eta	14.23	4.80	0.66	4.93	4.89	4.38	3.60	33.57
1st,mid-eta	39.33	14.38	1.63	11.64	9.83	8.58	15.03	64.30
1st,high-eta	81.72	34.23	5.72	17.51	40.46	35.10	91.38	162.67
2nd,low-eta	5.55	1.51	0.25	3.18	1.98	1.93	0.25	11.91
2nd,mid-eta	8.36	2.61	0.49	4.43	6.45	6.20	1.20	23.58
2nd,high-eta	16.70	5.83	1.23	8.11	19.55	17.63	4.05	57.90
3rd,low-eta	3.16	0.48	0.06	1.40	1.53	1.47	0.27	7.41
3rd,mid-eta	3.09	0.47	0.05	1.31	1.25	1.21	0.32	6.41
3rd,high-eta	2.95	0.48	0.05	1.21	1.06	0.97	0.46	7.32

Table 5.10 Neutron and photon fluences and charged particles currents predicted by FLUKA for the AV16 geometry layout. Scoring surfaces used are shown in Figure 5.16.

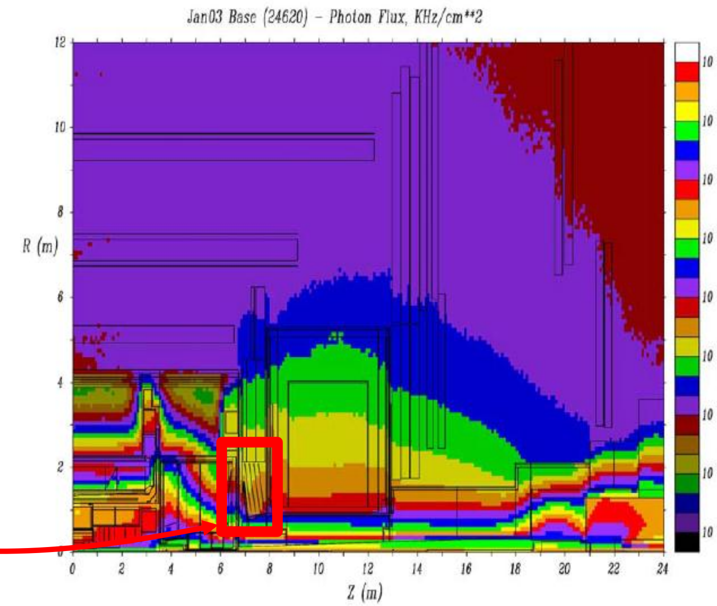


Figure 5.13 Photon flux in a full Atlas quadrant (GCALOR – Jan03).

<u>For LHC (L = 10^{34} cm^{-2} s^{-1}):</u>
Hottest region for gamma (E> 30 keV) in muon spectrometer is in forward CSC region:
~18 kHz/cm² = 1.8 10^4 Hz/cm²

<u>For 10 years of HL-LHC (assuming 1 y = 10^7 s):</u>
x5 Lumi increase
x3 security factor
x10 year

- Total of time equivalent: 1.5 10^9 sec

- **In hottest region ~2.7 10^{13} gamma / cm²** during 10 years of HL-LHC exposure

COCASE. Gamma irradiation facility at CEA Saclay

COCASE (IRFU)

Source de COBalt.

CASEmate.

Source activity in summer 2005:

17 Cu ~ 630 GBq = 6.3 10^{11} Hz
Minimum distance ~10 cm, ~30 deg. half-ang.
Mid of January 2012, (~6.5 y later, $T_{1/2}$ ^{60}Co ~ 5.27 y),
268 G.Bq (cf. R.C.) => 2.7 10^{11} decay / s

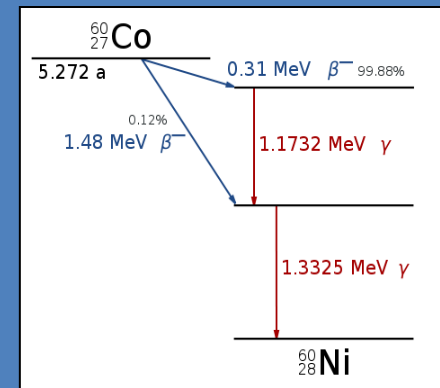
If at 50 cm from cobalt source:

- Solid angle ~ 3.1 10^4 cm^2
- 8.7 10^6 decay / cm^2 / sec x 2 ~ 1.7 10^7 gamma /cm^2 /sec
- Need 1.55 10^6 sec = 430 hours = 17.9 days

At 20 cm from cobalt source (reduce by $(5/2)^2$) **=> 2.87 days**

(Atlas hottest region ~2.7 10^{13} gamma / cm^2 for 10 years of HL-LHC)

(Cobalt decay emits two gammas together: one at 1.33 MeV + one at 1.17 MeV)



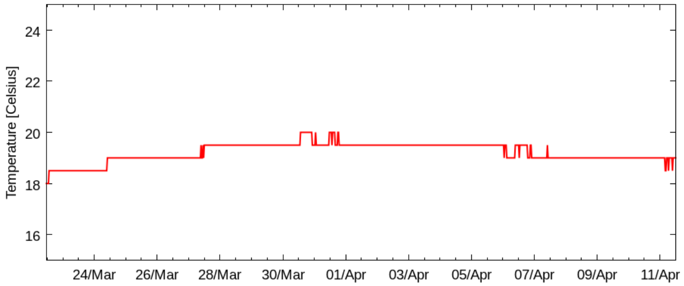
COCASE gamma ray facility: Installation and irradiation monitoring

Source de Cobalt 60 placed at 50cm from the source :

- 2 gammas à 1.33Mev et 1.17 MeV
    - 2.7.10^{11} désintégrations/s

20 days of exposure for 10 years of HL-LHC

A temperature control system kept the room at constant temperature.

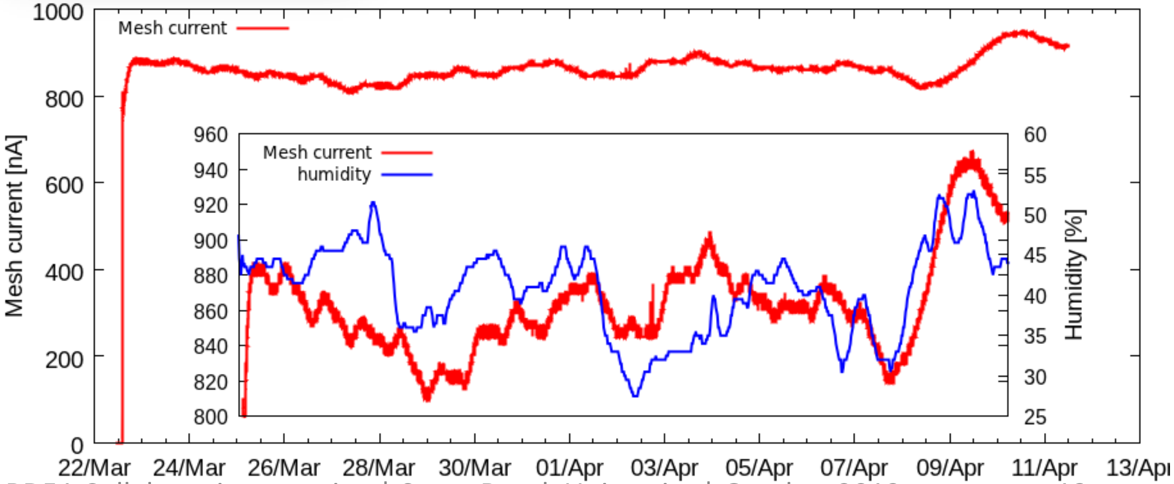


Gamma exposure between 22nd of March and 11th of April (2012).

Total exposure time : 480 hours

Total integrated charge : 1484 mC

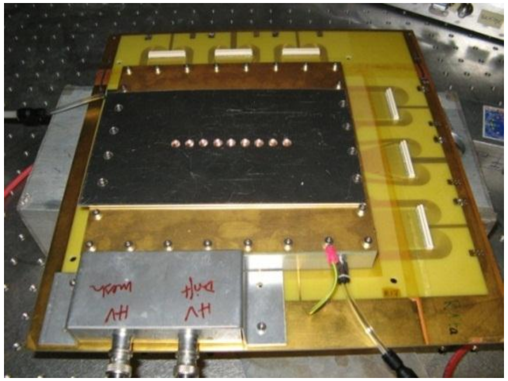
Mean mesh current : 858.4 nA



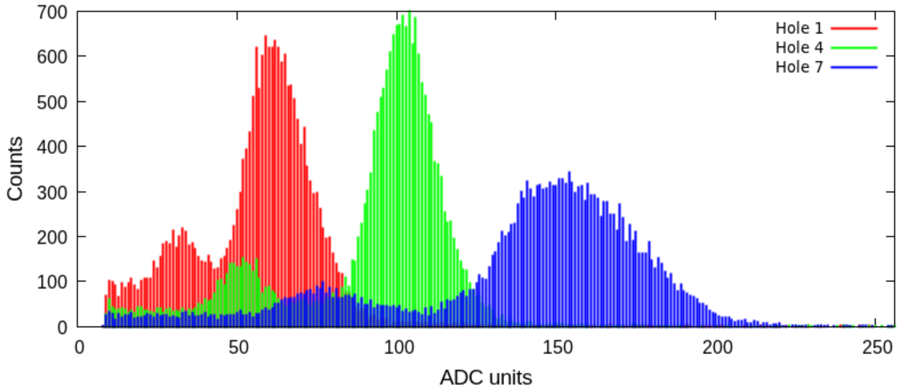
Gamma irradiation: Relative gain before and after irradiation

Measurements at different position were performed by using a mask with several equidistant holes over the active region of the detector (Same mask used along all the aging tests).

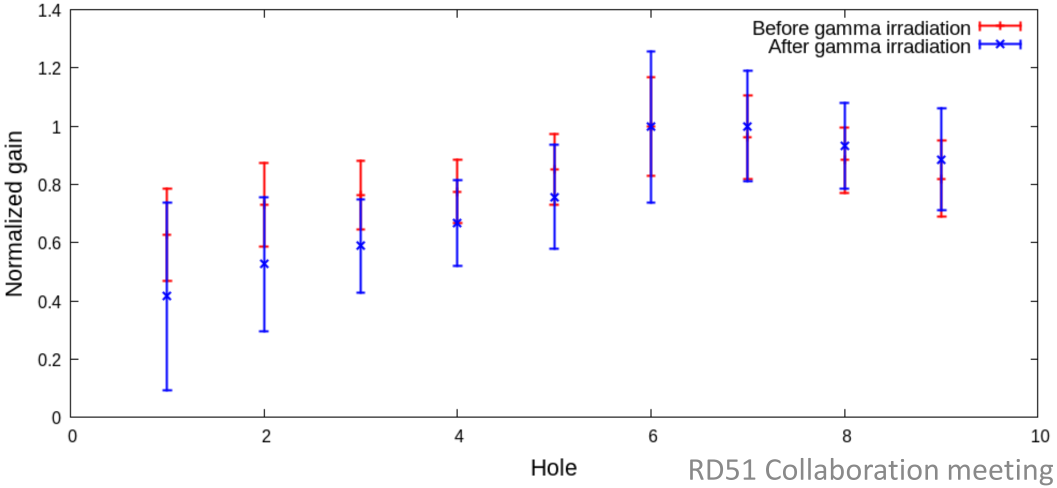
9 Holes mask used



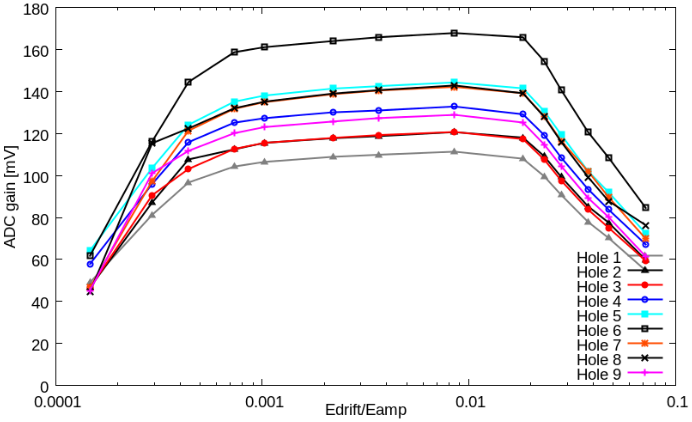
Fe55 source calibrations at different hole positions



Gain profile measured at the 9 reference points



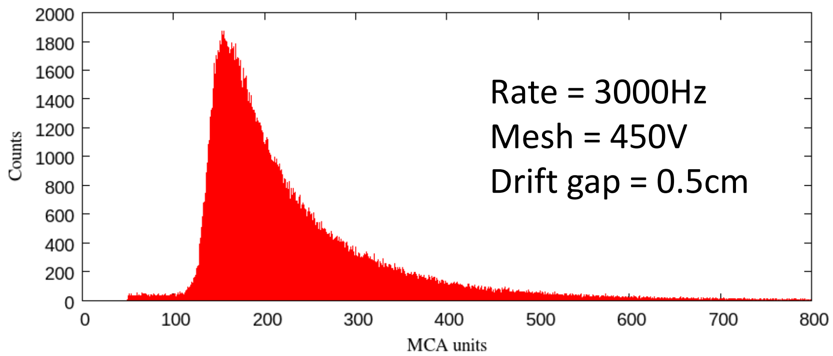
Detector transparency



Alpha irradiation

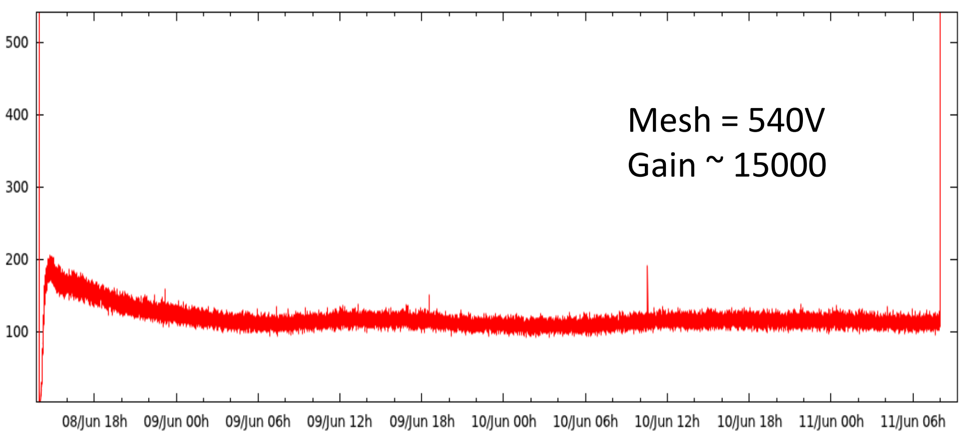
Alpha source installed inside the chamber and centered just on top of the drift grid.

<u>Alpha spectrum</u>

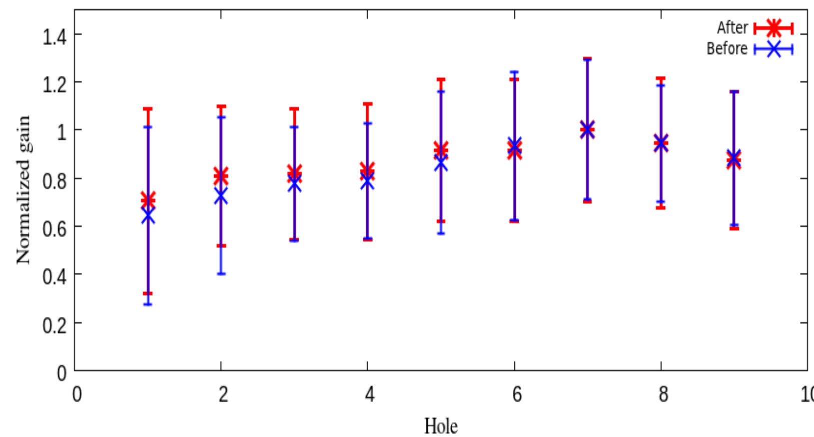


- ^{241}Am alpha in Ar+10%CO_2 produces 30 to 60.10^3 in a 5 mm conversion gap
  → gain 7000, “spark” conditions
- The detector was exposed for 66 hours with 3 kHz alpha rate and a mesh current ≥100 nA
- Total number of sparks is ≥ 500 x 10^6.

<u>Mesh current during alpha irradiation</u>



<u>Gain profile before and after irradiation</u>



Conclusion

Two X-ray irradiation periods had place at the detector in two different regions with a charge generation equivalent to 5 years of HL-LHC each.

Several neutron irradiation periods had place at Orphee reactor, corresponding to the equivalent 10 years of HL-LHC.

Gamma rays illumination by using a high intensity Cobaltum source, 10 years HL-LHC equivalent.

Irradiation with an alpha source to produce streamer like conditions has been done up to ~ 500.10^6 sparks equivalent.

→ Future tests could be performed with controlled amounts of Radon in the detector to have a global irradiation.
→ Long period ageing are kept in mind.
→ Material irradiaton in cold neutron beam are foreseen (depending on Orphée restart status)
→ Same studies are foreseen for the final prototype